4 FIBERS - NATURAL

4.1 Analytical Approach

4.1.1 List and describe each textile item. Include the label information as to fiber content, brand or manufacturer, manufacturer's numbers such as the RN# or WPL# and the size. Include a brief description of any design, logos or lettering present. Make a notation as to whether the Item is intact or not - buttons missing, apparent rips or tears, etc.

4.1.2 Vegetable fibers include the most important of all textile fibers, cotton, together with flax, hemp, jute and other fibers which have been produced by plants. A primary component of plant fibers is cellulose.

4.1.3 Animal fibers include wool and other hair fibers, and fibers, such as silk, produced as filaments by cocoon-spinning creatures. These animal hair fibers are composed of proteins.

4.1.4 Often vegetable fibers and animal hair fibers (animal hairs used in textiles) can be identified by an examination of the mounted fiber on a glass microscope slide (using either water, xylene substitute, Permount or Protexx). Cotton, wool, rabbit hair, etc. can be identified based upon their microscopic characteristics and comparison with in-house standard collections, as necessary.

4.1.5 Numerous excellent references are available to supplement the basics described herein and therefore, that material will not be duplicated here. This is particularly true for the areas of ropes and cordage, buttons, and fabric construction, in addition to identification and comparison of natural fibers.

4.1.6 Minimum Standards and Controls

4.1.6.1 The comparison microscope data of all positive, probative associations will be verified by a second qualified examiner. The original fiber worksheet(s) will be initialed and dated by the second examiner in the space labeled "verification". The verification includes the K and Q comparison of those features determinable by viewing with both transmitted light and polarized light.

4.1.6.2 Any mounting media with a stated expiration date will not automatically be discarded after the stated date. As long as the mounting media has not yellowed and continues to "flow" properly, as determined by the examiner, then it may continue to be used.

4.2 Recovery of Hairs and/or Fibers

4.2.1 Purpose

To examine evidence to locate, recover and preserve hairs/fibers for identification and/or comparison purposes.

4.2.2 Summary

4.2.2.1 Generally speaking, submitting the article or articles of evidence to the laboratory for the examiner to process is the best approach to the recovery of hairs and/or fibers. There are instances where this is not practical or possible, such as recovering hairs and/or fibers from wall-to-wall carpeting, a large piece of furniture, or a vehicle. In these instances, the recovery may be accomplished at the scene with the aid of an alternative light source, if available, and the recovered hairs and/or fibers submitted for examination.

4.2.2.2 The order of preference for the recovery of hairs and/or fibers is manual removal with forceps followed by taping with Post-It Notes. Gentle scraping may be necessary in certain instances. Vacuuming is rarely, if ever, performed because the debris recovered represents far more than recent hair and/or fiber transfers. However, hairs and/or fibers recovered with these methods, when submitted as evidence, will be examined to the best of the laboratory's ability.

4.2.3 Minimum Standards and Control

4.2.3.1 The examiner shall change the examination paper between victim and suspect or scene exhibits. The examiner may change the paper between multiple victim, suspect or scene items, as necessary.

4.2.3.2 There should be only one exhibit opened at a time, unless two separate areas exist for this purpose.

4.2.3.3 The examiner shall change gloves and clean their tools between examining the evidence from the victim and the evidence from the suspect.

4.2.3.4 If possible, the victim's evidence and suspect's evidence should be examined in separate rooms. If this is not possible, then the separation of victim and suspect evidence in time and/or space will be necessary. Document in case file notes.

4.2.3.5 Use separate laboratory coats and evidence collection rooms, if available, for examining materials from victim and suspect to prevent possible cross-transfer contamination.

4.2.3.6 Avoid drafts around the examination area.

4.2.4 Analytical Procedure

4.2.4.1 Spread a clean piece of paper on the examination surface.

4.2.4.2 Examine each item of evidence visually or with the aid of an illuminated magnifier, UV light or alternative light source.

4.2.4.2.1 If the item being examined contains hairs and/or fibers that are readily visible, collect these hairs and/or fibers with forceps. As hairs and/or fibers are collected, they should be placed in glassine packets or affixed to Post-It notes.

4.2.4.2.2 Take care with bulky items which require repositioning on the examination table, to avoid the loss of hairs and/or fibers in the repositioning process.

4.2.4.3 Post-It Notes or other light tack adhesive tapes may be used to recover hairs and/or fibers. The adhesive surface is placed on the item being examined and then pulled away. Hairs and/or fibers will adhere to the adhesive on the tape.

4.2.4.3.1 This method may be especially useful on large items or dark-colored items on which hairs and fibers of interest may be difficult to see.

4.2.4.4 Scraping is generally discouraged as a method of collection for hairs and/or fibers. If scraping is necessary, the item to be examined is suspended above the examination surface and very gently scraped with a spatula. Scraping in a downward direction allows surface hairs and/or fibers to fall onto the examination paper for collection.

4.3 Natural Fiber Identification

4.3.1 Purpose

The purpose of natural fiber identification is to identify vegetable fibers and animal hair fibers.

4.3.2 Safety Considerations

4.3.2.1 The use of xylene substitute, Permount, Pro-Texx or Meltmount to mount the vegetable fibers or animal hair fibers requires caution. The process may be carried out in a well ventilated area or by using a "Nederman" point-of-use vent, if one is available.

4.3.2.2 If scale casts are required (for animal hair fiber identification), it is best to use the same precautions as above. The medium for the casts is either "Polaroid" film coater or clear fingernail polish.

4.3.3 Minimum Standards and Controls

4.3.3.1 A reference collection of vegetable fibers, animal hair fibers, and silk, mounted on glass microscope slides is necessary.

4.3.3.2 A reference collection of vegetable fibers, animal hair fibers and silk, not mounted on glass microscope slides but available for use in the preparation of cross-sections, is necessary.

4.3.4 Analytical Procedures

4.3.4.1 Mount the specimen on a glass microscope slide (using either water, xylene substitute, Permount, Pro-Texx or Meltmount).

4.3.4.2 Using a compound microscope, examine the specimen and compare with reference hair fiber and/or fiber standards. If the specimen can be identified at this stage (for example, cotton or rabbit hair) it is not necessary to proceed.

4.3.4.3 Cross-sections may be performed as needed (for example, to aid in the identification of ramie or flax). (Procedure is outlined below).

4.3.4.4 Scale casts may be performed as needed (Procedure is outlined below).

4.3.4.5 The dry twist test may be performed as needed (for example, to differentiate flax and hemp). (Procedure is outlined below).

- See below for Identifying Characteristics of Some of the More Common Animal Fibers (Hair and Silk) Used in Textiles and Identifying Characteristics of Some Common Plant Fibers.

4.3.4.6 Identifying Characteristics of Some of the More Common Animal Fibers (Hair and Silk) Used in Textiles

WOOL - pronounced scales, usually no pigment, generally white if undyed, diameter range 10-70 μm, cut ends

CASHMERE - pronounced scales, centric pigment distribution, average diameter 15-16 μm, no medulla in fine fibers, root ends present, generally not white

MOHAIR - faint scales, no pigment, diameter range of 10-90 μm, generally white if undyed, ovate bodies present, short longitudinal streaks in cortex

CAMEL - faint scales, centric streaky and granular pigment, average diameter of 18 μm, sometimes interrupted medulla

ALPACA - faint serrated scales, medulla usually present and is oval to elongated with kidney or dumbbell shape

LLAMA - faint serrated scales, medulla usually present and is oval to elongated with kidney or dumbbell shape

VICUNA - faint scales, medulla seldom present, fine hairs with average diameter of 13-14 μm, guard hairs also

RABBIT - uniserial to multiserial medulla (ladder-like)

HORSE - coronal scales, eccentric pigment distribution, medulla is over 1/2 diameter of hair

SILK (BOMBYX MON) - twin continuous filaments, cemented together, degummed filaments are fine, uniform, with no visible internal structure, triangular cross section with rounded corner

SILK (TUSSAH) - brownish, coarse, ribbon-like with striated and granular structure, wedge-shaped cross section uncultivated silk worms which produce fibers of dark and light colors

4.3.4.7 Identifying Characteristics of Some Common Plant Fibers

COTTON - looks like twisted, flattened tubes (convoluted), very irregular in appearance, remains bright in all orientations between crossed polars

Mercerized Cotton: not as twisted, somewhat featureless, but still not regular

KAPOK - smooth, cylindrical, hollow, thin-walled, frequently bent over on itself, tapers to a point with other end having a bulbous base with annular or reticular markings

FLAX - (linen) small, regular lumen, regular diameter; (linen) characteristic x-shaped cross markings usually exists as ultimates; twist-test: clockwise; swells rapidly and uniformly with cupric ammonium hydroxide and dissolves except for thread of protoplasm

JUTE - irregular lumen, regular diameter; occasional nodes and markings, not distinctive; usually in bundles; twist-test: counterclockwise, x-section round to oval

HEMP - lumen not always evident (large when seen), irregular diameter; many cross-markings; twist-test: counterclockwise; swells slowly with contractions with cuprammonium hydroxide

RAMIE - irregular lumen, large; irregular diameter, largest natural fiber; many characteristic cross-markings, many ridges and striations; twist-test: clockwise; cross section: displays radical cracks on cross sections

SISAL - irregular lumen; spiral elements present; acicular crystal present; stigmata present; twist-test: counterclockwise

ABACA - (manila) regular lumen, regular diameter; no distinctive (manila) markings; stigmata present; naturally buoyant; stigmata present in ash

COIR - very short fibers, irregular lumen; surface covered with stigmata in longitudinal rows

4.3.4.8 Cross-Sections

4.3.4.8.1 Cross-sections must be made to identify some vegetable fibers. Flax and ramie are best differentiated by cross-section.

4.3.4.9 The Joliff slide procedure works well for cross-sectioning of vegetable fibers and animal hair fibers. Joliff slides are black vinyl plastic appropriately 0.4 mm thick with holes 0.5 mm in diameter. The packing thread consists of any fibers of simple cross-section and contrasting color. Rayon or cotton is typically employed.

4.3.4.9.1 A loop of packing fiber is wound around the fingers and just drawn into one of the holes with a needle threader of strong, thin wire.

4.3.4.9.2 The exact amount of fiber needed is found the first time by trial and error. It must fill the hole tightly enough so that it does not pull out when cut, but not so tightly that it cannot be drawn without forming a bulge in the plastic. Once found this quantity is recorded for future reference.

4.3.4.9.3 One to one half dozen fibers to be sectioned are chosen. A greater number of fibers will require a corresponding decrease in the amount of packing fiber used.

4.3.4.9.4 The fiber(s) is placed in the bundle and pulled just enough so that the fiber of interest is drawn through and describes a U-shape.

4.3.4.9.5 The fiber(s) is cut flush on both sides with a fresh single-edged razor blade. It is usually most convenient to trim both sides first with scissors.

4.3.4.9.6 Using a comparison microscope, the cross-sections can be compared to known cross-sections to make identifications.

4.3.4.10 Scale casts may be performed, (as outlined below) as needed. Two (2) methods are as follows:

4.3.4.10.1 "Polaroid" Coater Method

4.3.4.10.1.1 Make two or three passes along the length of a clean microscope slide using a "Polaroid" film coater. Wet the slide thoroughly and not overly thick.

4.3.4.10.1.2 Place the hair fiber on the microscope slide ensuring that the hair fiber is completely imbedded in the casting material but is not covered.

4.3.4.10.1.3 Allow the coating to dry.

4.3.4.10.1.4 Gently peel the hair fiber from the slide. An impression of the scales will remain on the slide in the coating.

4.3.4.10.1.5 With a sharp scalpel, slice away the excess coating protruding above the flat surface of the scale cast. Be careful not to slice too deeply into the coating itself.

4.3.4.10.1.6 Observe the scale impression microscopically with transmitted illumination.

4.3.4.10.2 Clear Fingernail Polish Method

4.3.4.10.2.1 On a clean microscope slide, place a thin layer of clear fingernail polish which has a very low viscosity (diluted with acetone).

4.3.4.10.2.2 With fine forceps, place the hair fiber onto the nail polish ensuring that the hair is completely imbedded in the casting material but not covered.

4.3.4.10.2.3 Allow the polish to dry overnight.

4.3.4.10.2.4 Gently peel the hair fiber from the slide. An impression of the scales will remain on the slide in the coating.

4.3.4.10.2.5 With a sharp scalpel, slice away the excess coating protruding above the flat surface of the scale cast. Be careful not to slice too deeply into the coating itself.

4.3.4.10.2.6 Observe the scale impression microscopically with transmitted illumination.

4.3.4.10.3 Dry Twist Test

Several vegetable fibers can be differentiated quickly by use of the dry twist test as follows:

4.3.4.10.3.1 Soak fiber(s) in water for a few minutes until thoroughly wet.

4.3.4.10.3.2 Remove a single fiber, holding it at one end with forceps.

4.3.4.10.3.3 Hold the fiber, with the free end toward the observer, over a hot surface, such as a hot plate.

4.3.4.10.3.4 Observe whether the fiber rotates in a clockwise or counterclockwise direction (or if the direction is indecisive) as the fiber dries.

4.3.4.10.3.5 Make several cross checks if a possibility of more than one type of fiber is present.

4.3.4.10.3.6 See below for Table of Directions of Twist for Most Natural Fibers.

DIRECTIONS OF TWIST FOR MOST NATURAL FIBERS

Clockwise	Counterclockwise	Alternating Directions	Clockwise or Indecisive	Variable or none
Flax	Hemp	Cotton	Coir	Kapok(Indian)
Ramie	Jute			
Kapok (Java)	Manila			
Nettle fiber	Sisal			
	Henequen			

4.3.5 References

4.3.5.1 Appleyard, H.M., Guide To The Identification of Animal Fibers; Wool Industries Research Association: Leeds, England 1960.

4.3.5.2 Cook, Gordon, Handbook of Textile Fibers, Fifth Edition 1984.

4.3.5.3 Hicks, John, Microscopy of Hair, FBI Issue 2, January 1977.

4.3.5.4 Introduction To Hairs and Fibers (Training Materials) F.B.I., March 1998.

4.3.5.5 Palenik, S. and Fitzsimons, Forensic Microscopy, Fiber Cross-Sections: Part II, Microscope 1990 (38) pages 313-320.

4.4 Natural Fiber Comparison

4.4.1 Purpose

To determine if fibers from different sources could have had a common origin.

Special considerations that should be noted when performing fiber comparisons:

4.4.1.1 The comparison of questioned fibers with fibers from a known source is performed in every step of the examination once the questioned fibers are recovered and the standard fibers are collected from a known source.

4.4.1.2 The examiner can approach the fiber comparison by setting out to show that the samples are different. The failure to detect any significant differences, after exhausting the methodology available to the examiner, results in the conclusion that the fibers could have the same origin.

4.4.1.3 Generally, destructive testing is performed after all non-destructive testing is complete when sample size is limited.

4.4.2 Minimum Standards and Controls

4.4.2.1 The comparison microscope data of all positive, probative associations will be verified by a second qualified examiner. The original fiber worksheet(s) will be initialed and dated by the second examiner in the space labeled “verification”. The verification includes the K and Q comparison of those features determinable by viewing with both transmitted light and polarized light.

4.4.2.2 Reagents shall be prepared in accordance with the QA/QC protocol (see Appendix 4) and reagent reliability checks will be recorded.

4.4.2.3 The known and questioned fibers shall be examined at the same time, in a side-by-side fashion. The results shall be recorded on a fiber worksheet(s).

4.4.2.4 Extreme caution must be used when handling known and questioned fibers to avoid any possibility for cross-contamination.

4.4.2.5 Use the same mounting media for known and questioned fibers.

4.4.3 Analytical Procedures

4.4.3.1 Polarized Light Microscopy

4.4.3.1.1 Prepare temporary or permanent mounts of the known and questioned fibers.

4.4.3.1.2 Observe both physical and optical properties of the fibers using either the stand-alone polarized light microscope or the comparison polarized light microscope. NOTE: If the fibers are observed with the stand-alone polarized light microscope at this time, they MUST also be compared on the comparison microscope at some time during the examination.

4.4.3.1.3 Using the fiber worksheet (Appendix 19), record the physical and optical properties. These will include at a minimum: color, diameter, extinction, birefringence, sign of elongation and optical cross-section.

4.4.3.2 Fluorescence Microscopy

Some fibers fluoresce when exposed to different wavelengths of light. Of those fibers, the wavelength and intensity of emission under different excitation wavelengths are important. Fluorescence can be caused by optical brighteners, detergents, bleaching agents, dyes, the chemical structures or other additives.

4.4.3.2.1 Generally done at the same time as the observation of physical and optical properties.

4.4.3.2.2 Fluorescence cubes to be used are **WU** (wide UV 330 – 385 nm), **WBV** (wide blue violet – range 400 – 440 nm), **WB** (wide blue – range 450 – 480 nm) and **WG** (wide green – range 510 – 550 nm). These filter blocks include excitation and barrier filters. Record observations on the fluorescence worksheet.

4.4.3.2.3 A significant difference in fluorescent properties between known and questioned fibers at any of these excitation wavelengths is cause for elimination.

4.4.3.2.4 Certain mounting media will fluoresce. Non-fluorescing media should be used to achieve optimum contrast with the background.

4.4.3.3 Comparison Microscope

4.4.3.3.1 Observe known and questioned fibers in temporary or permanent mounts with the comparison microscope.

4.4.3.3.2 Record match or nonmatch.

4.4.3.4 Microspectrophotometry

4.4.3.4.1 Obtain spectra of questioned and known fibers mounted in the same media. If sample amount is sufficient, mount the fibers in the permanent mount of choice for best data.

4.4.3.4.2 Range of colors, color intensity and distribution as well as cross-sectional shape should be considered when determining the number of spectra to be collected for the comparison on the known and questioned fibers.

4.4.3.4.3 Comparison should be performed by overlaying the known and questioned spectra. Any major discrepancies between the two are reason for elimination.

4.4.3.5 Cross-sections

Frequently the cross-section of a fiber can be determined from the longitudinal view, also known as optical cross-sectioning. This may be the only technique available for cross-sections if the questioned fiber is too short.

4.4.3.5.1 Prepare cross-sections of the known and questioned fibers, treating both the known and questioned fibers in the same manner, using either the method described in 4.4.4.8 or one of the following methods:

4.4.3.5.1.1 Polyethylene sheets - Single fibers are placed between two plastic sheets. The plastic “sandwich” is placed on a glass microscope slide, another slide or a cover slip is placed over the plastic “sandwich” and this is then transferred to a hot plate set on low. Some pressure may need to be applied as the plastic melts around the fiber. A new single-edged razor

blade or scalpel blade may be used to slice thin cross-sections of the sandwiched fiber. The remaining portion of fiber is easily removed by cutting and lifting away the plastic sheets.

4.4.3.5.1.2 Super Glue®Gel- Place the fibers to be cross-sectioned on a microscope slide. Add enough glue to cover the fibers. After fully drying, use a new single-edged razor blade or scalpel blade may be used to slice thin cross-sections of the fiber.

4.4.3.5.1.3 Norland Optical Adhesive 60® - Place the fibers to be cross-sectioned on a microscope slide. Add enough adhesive to cover the fibers. Expose to long wave ultraviolet light (320-400 nm) for approximately 5-10 minutes, or until completely cured. A new single-edged razor blade or scalpel blade may be used to slice thin cross-sections of the fiber.

4.4.3.5.2 Compare the prepared cross-sections with the comparison microscope and record observations.

4.4.3.6 Microchemical Tests

The chemicals and reagents used are at the discretion of the examiner and should be based upon results from other examinations and sample condition and quantity.

Observation of color reactions in the reagents allows the side-by-side comparison of the reaction of the dyes used in the known and questioned fibers.

4.4.3.6.1 Microchemical test reagents that are used are: 75% sulfuric acid, concentrated nitric acid, concentrated hydrochloric acid, and LeRosen.

4.4.3.6.2 Cut small portions of the known and questioned fibers and place them in welled spot plates or on a microscope slide under a cover slip.

4.4.3.6.3 Add a drop or two of the microchemical test reagent. Observe and record the reaction with the aid of the stereomicroscope. Record any color changes that occur using the fiber worksheet.

4.4.4 References

4.4.4.1 Technical Working Group for Materials Analysis, Forensic Fiber Examination Guidelines, January 1998.

4.5 Documentation

4.5.1 The examiner's notes will include a description of the known item (for example, coat) listing color, size, (manufacturer and fiber content, if available).

4.5.2 The examiner's notes will include a description of the questioned fiber(s), including color and documentation of how the fiber was identified (for example, microscopic examination, scale pattern, cross-section, dry twist test etc.).

4.5.3 The fiber content of the known will be confirmed/determined.

4.5.4 Worksheets and microspectrophotometry data will be included as appropriate.

4.6 Report Wording

4.6.1 Unknown fibers or hair fibers that only require identification are reported as such:

The fiber in Item ___ was identified as red wool (cotton, silk, etc.)

4.6.2 If the known and questioned fibers can be eliminated based upon any of the testing the report will generally read:

The Item __ fibers could not be associated with the Item __ fibers due to differences in _____. State either color, microscopic properties, optical properties, or chemical properties as the reason for the differences.

4.6.3 If the known and questioned fibers cannot be eliminated based upon any of the testing the report will generally read:

4.6.3.1 The Item __ and __ fibers matched in physical, chemical and optical properties and could have had a common origin.

4.6.3.2 Several of the fibers recovered from Item __ matched the fibers composing the Item __ _____ (carpet, shirt, sweater, blanket, etc.) in physical, chemical and optical properties. It was concluded that these matching fibers could have had a common origin.

4.6.3.3 The red wool (cotton, silk, etc.) fiber in Item ___ matched the fibers composing the _____ (known) in (physical, chemical and optical properties). Therefore, the Item ___ red wool fiber could have originated from the _____(known).

4.6.4 If foreign fibers were recovered and knowns are being requested for comparison purposes the report will generally read:

4.6.4.1 Foreign (color and/or type) fibers were recovered from Item(s) __ which were suitable for comparison purposes. If a known source is located, resubmit Item(s) __ along with the known for comparison purposes.

4.6.4.2 It may also be appropriate to include a general statement as follows:

The fibers recovered from Item _____ consisted of various colors of natural and apparent synthetic fibers.

4.6.5 If the examiner is requested to make a comparison based on fabric construction the report will generally read:

Items ____ were consistent in overall color and (knitted or weave) construction and were composed of fibers which matched in physical, chemical and optical properties. It was concluded that these Items could have once been a part of the same set (or single unit).

4.6.6 Each examiner should be able to convey information on how "common" a particular fiber type may be. For instance, white (colorless) cotton or white (colorless) and "indigo" blue cotton fibers from blue jeans often are considered to have no evidential value due to their prevalence.

4.6.7 Generally, textile materials are mass produced and it is not possible to state that a fiber originated from a particular garment to the exclusion of all other textile materials having the same color and type of fibers in their construction.

4.6.8 A disclaimer statement may be used (for example: It is pointed out that fibers do not possess a sufficient number of unique individual microscopic characteristics to be positively identified as having originated from a particular source to the exclusion of all others.)

4.6.9 For report styles that list the Item number first, delete references to the Item number in the result statement.

♦End